

THURSDAY, MARCH 9, 1882

VIVISECTION

THE discussion on this subject which has been carried on during the last few months in the *Nineteenth Century* and *Fortnightly Review* has now, we think, proceeded sufficiently far to render it desirable that we should give our readers a short summary of its progress. But as there are altogether some twelve or fourteen articles to be dealt with, we shall only have space to supply a general analysis of the facts and arguments, without being able to give an abstract of each article separately.

As regards the general tone or manner of pleading, there can be no doubt that the advantage inclines largely to the side of the physiologists; for while—with perhaps a slight exception in the case of some of the passages in the essays by Prof. Owen and Dr. Wilks—the physiologists state their arguments in a calm and tolerant spirit, the essays on the other side—with the exception of one by Mr. Hutton—present, in a painfully marked degree, the features of bitterness and ill temper. But, disregarding this conspicuous difference in the style of writing, we shall endeavour to give an analysis of the arguments on both sides, the impartiality of which shall not be affected by the fixed opinion which this journal has always held upon the subject.

The utility of Vivisection is upheld by Sir James Paget, Prof. Owen, Dr. Wilks, Dr. Carpenter, Sir William Gull, Mr. Fleming, Dr. Brunton, and Dr. Yeo. This is done, not merely by stating the general truth, obviously *a priori*, that “it would be more reasonable to hope to make out the machinery of a watch by looking at it, than to hope to understand the mechanism of a living animal by mere contemplation”; but chiefly by enumerating instances in the past history of research where important advances of knowledge have been made by vivisection, and could not have been made otherwise. The cases mentioned are very numerous, so we must restrict ourselves to mentioning the more important.

Sir James Paget says—and on such a topic he is entitled to speak with at least an unsurpassed authority—“Before Hunter’s time it is nearly certain that ninety-five out of a hundred persons who had aneurism of the principal artery of the lower limb died of it. . . . At the present time it is as certain that of a hundred persons with the same disease less than ten die,” and if we contemplate cases of aneurism in all other arteries, as well as deaths from bleeding after large operations, the saving of life due to Hunter’s experiments is seen to be “very large.” But Sir James does not needlessly prolong his article by enumerating specific instances; he says: “others have already abundantly illustrated them; I will rather suggest some general considerations on the whole subject. Looking back over the improvements of practical medicine and surgery during my own observation of them in nearly fifty years, I see great numbers of means effectual for the saving of lives and for the detection, prevention, or quicker remedy of diseases and physical disabilities, all obtained by means of knowledge to the acquirement or safe use of which experiments on animals

have contributed. There is scarcely an operation in surgery of which the mortality is now more than half as great as it was forty years ago; scarcely a serious injury of which the consequences are half as serious; several diseases are remediable which used to be nearly always fatal; potent medicines have been introduced and safely used; altogether such a quantity of life and of working power has been saved by lately-acquired knowledge as is truly past counting. And in these advantages our domestic animals have had due share of the improvement of veterinary medicine.”

The next paper in the series is by Prof. Owen, and is concerned mainly with the history of the indispensable part which vivisection played in Harvey’s discovery of the circulation of the blood and in Hunter’s experiments on the ligature of arteries. Although the latter topic occupies common ground with a part of Sir James Paget’s paper, the overlapping due to independent writing is not to be regretted, because Prof. Owen traces the history of the subject into more detail, in order to expose the fallacy of the anti-vivisectionists, who say that Hunter was anticipated in his results by other surgeons working by other methods. This, we think, he is completely successful in doing—so much so, indeed, that Mrs. Algernon Kingsford M.D., who supplies an essay in a succeeding number of the *Nineteenth Century* on “The Uselessness of Vivisection,” while disputing Sir James Paget’s mere statement of the fact that the surgical treatment of aneurism is due to Hunter’s experiments on deer, nevertheless finds it convenient entirely to ignore the historical details which are given by Prof. Owen; and the same remarks apply to this lady’s treatment—or rather evasion—of the facts concerning Harvey’s discovery of the circulation of the blood.

Dr. Wilks makes utility the central portion of his argument, and gives so many instances of the service which vivisection has rendered that we cannot here quote them. The instances he refers to concern the heart, circulation, functions of the brain, spinal cord, and nervous system generally, including its influence over the heart, lungs, stomach, kidneys, bladder, skin, and muscles, &c. “What,” he asks, quoting from Prof. Humphrey, “has been the influence of this upon medical treatment? . . . Take away the knowledge which we have received through vivisection, and conceive what a chaos would be our knowledge of the human body, and our ideas of the treatment of the diseases of the human body; you can scarcely conceive to what we should be reduced. Every man in the whole history of medicine, every man who has made real advances in the knowledge of the workings of the human body, has done it through vivisection.”

The utility of vivisection is further shown by Sir W. Gull, Dr. Carpenter, Mr. Fleming, and Dr. Brunton. The former alludes to the discovery of the lymphatic system, and of the capillary circulation, to “the great advances made by Boyle, Mayow, and Lower, in the same century”; and more especially to the work of Claude Bernard on animal heat. This is specially alluded to in consequence of Miss Cobbe in her article “writing of the title of Claude Bernard to be honoured by physiologists, saying that such title is, at least partly, based on the invention of a stove which should enable him to

watch the process of 'baking dogs alive'—a statement "calculated, if not intended to convey a totally false impression both of the purpose and the details of these memorable experiments." The importance of the latter in relation to preparing the way for a full understanding of the deadly phenomena of fever is then clearly exhibited, together with the fact that "if a dog be put into a heated chamber and his blood be raised to the temperature of a bird's, he quickly dies"—so that the "baking alive" really means raising the temperature of the dog's blood through ten degrees. Every year in this country alone 40,000 persons die of scarlet and typhoid fevers—"baked alive" by them; and this constitutes but a small part of the annual deaths in which exalted temperature is a fatal factor. No wonder therefore that medical men pay tribute to the memory of Bernard for opening the way to an understanding of the subject, such that "this fiery furnace, with its uncounted millions of victims, science hopes to close; and it is quite reasonable to believe that the time will come when fever will be as much under our control as are the movements of a chronometer." When to this it is added that "Bernard, in these experiments on fever, sacrificed two pigeons, two guinea-pigs, less than twenty rabbits, and six dogs," we cannot think that the selection by Miss. Cobbe of her favourite atrocity is a very fortunate one.

Sir William Gull proceeds to consider the great gains which have accrued to medical science through some of the experiments of Magendie, and those of Marshall Hall; and Dr. Brunton, in a singularly telling article, shows how in an ordinary diagnosis it is impossible to advance a step without using at every point knowledge gained by experiments on animals. He also appeals to the British Pharmacopœia to prove that to vivisection "we owe the introduction of the most valuable of our new remedies." Between the editions of 1864 and 1867 there are added seven new drugs, of which at least the two most useful—viz. carbolic acid and physostigma—are due to vivisection. Again, between the editions of 1867 and 1874 we find eleven new remedies, of which the three most useful—pepsine, chloral, and a nitrite of amyl—were discovered, or their uses perfected, by experiments on animals. So that, without considering "many other new remedies which are still on their trial, and which will, in all probability, be added to the next edition of the Pharmacopœia, it is a matter of already accomplished fact that "the introduction of nearly all the most valuable new remedies which have been added to the Pharmacopœia since the year 1864" have been discovered by vivisection.

Still confining ourselves to the question of utility, we have next to notice the essay by Mr. Fleming, who undertakes to show that even in the exclusive interests of animals themselves, it is most ill-advised to tie the hands of science in its investigation of disease. Anthrax alone, in a single district of France, kills about 178,000 sheep a year, and in 1857 100,000 horses perished from this disease in Russia alone. Many other equally startling statistics are given; and now, owing to the laboratory experiments of Pasteur and others, "there is no longer any doubt as to the value of protective inoculation;" and the same method has been found equally effectual in protecting poultry from "fowl-cholera." It

is not improbable that hydrophobia, glanders, cattle plague, pleuro-pneumonia, swine-plague, sheep small-pox distemper, and tuberculosis, will all admit, by modifications of the same method, of being similarly brought under control.

In connection with utility we have space only to refer to one other case, but this the most conspicuous. We allude to the work of Lister, which, as Dr. Carpenter says, "constitutes by far the greatest single improvement ever introduced into surgical practice," and which, as Dr. Wilks says, "has been the means of saving the lives of thousands every year, both in England and on the Continent." Yet Prof. Lister "found that he was obliged to discontinue his important investigations or conduct them abroad. He chose the latter course, and went to France; for, he said, 'even with reference to small animals, the working of the Act is so vexatious as to be practically prohibitory of experiments by a private worker like myself, unless he chooses to incur the risk of breaking the law.'"

Such, then, is a brief abstract of the evidence on the head of utility. This evidence is not disputed by the writers on the other side, with the exception of Miss Cobbe and Mrs. Kingsford; but the writings of these ladies upon the subject are so extravagant and ill-advised that even an ignorant reader must feel their judgment upon this head to be valueless.¹ With the unanimous opinion before them of the International Medical Congress, the British Medical Congress, and of all persons whose knowledge of physiological science entitles them to be heard on this point, Lord Coleridge and Mr. Hutton adopt a line of argument which, so far at least, is more judicious. Lord Coleridge says: "I will not dispute with them as to the fact. A lawyer ought at any rate to know the folly of encountering an expert without the knowledge necessary for success in the conflict. I deny the practical conclusion sought to be drawn from it on grounds of another sort, which appear to me of overwhelming force." And Mr. Hutton says: "I have never believed all these experiments to be scientifically, or even medically, worthless," and he allows that some of them (inoculations) have been "very fruitful."

We may, then, take the evidence of utility as being beyond all question by any reasonable and impartial mind. Next let us consider the arguments which are adduced against vivisection other than the suicidal one of inutility. These may broadly be classed under two headings—those which assert that vivisection is immoral, and those which assert that it is irreligious.

In considering these arguments we may best begin with the essay of Lord Coleridge, and in doing so we find it difficult to strike the balance between our respect for the

¹ The authority of Sir W. Fergusson and of Sir Charles Bell is indeed quoted in support of the uselessness of vivisection to surgery, but their opinion on this subject—or rather the opinion of the former, because the latter did not live to see all the results alluded to by Sir James Paget—is so immeasurably outweighed by professorial opinion in general that it is interesting chiefly because of its isolated character. The only other feature in these papers that deserves the name of argument is that inference from the results of experiments on animals to the physiological economy of man may be erroneous, or even misleading. But what does this argument show? Surely not that, *for this reason*, experiments on the nearest analogues of the human body should not be made. No instance can be pointed to of a fatal or even deleterious mistake having been made as a consequence of any such erroneous inference, nor is it at all likely that such an instance can ever arise.

man, and our astonishment at the feebleness of his production. Taking as fair and unbiased a view as we can, it appears to us that, as a mere matter of pleading, if this is all that can be said, even by a Lord Chief Justice, in favour of abolishing physiological experiment, the physiologists could not well find a better advocate. Indeed, as the paper throughout shows ill-concealed evidence of intolerable irritation, its manner, as well as its matter, suggests that the writer himself begins to feel that he has committed a mistake in too early and too warmly espousing an irrational cause. But, be this as it may, we shall endeavour to state, as fairly as we can, the course of his argument.

We have already seen that he expressly disregards the question of utility, and bases his argument "on grounds of another sort." These grounds are that, even if practically useful to the extent claimed by physiologists and medical men, knowledge gained by vivisection ought not to be sought or tolerated, inasmuch as it is "unlawful," or "pursued by means which are immoral." Here, at least, we have a definite marking out of the "grounds" on which Lord Coleridge justifies his determination, as he says, "earnestly to support the Bill which Mr. Reid is about to submit to the House of Commons," *i.e.* the Bill for total abolition. We think, therefore, that it becomes a matter of importance clearly to define what is here meant by "immoral" and "unlawful." The only indication given by Lord Coleridge of such a definition is as follows: "I deny altogether that it concludes the question to admit that vivisection enlarges knowledge; I do not doubt that it does, but I deny that the pursuit of knowledge is in itself lawful; still more do I deny that the gaining knowledge justifies all means of gaining it." So far as these general propositions are concerned the principles of morality are obvious, and would be disputed by no one; but now for the special case of vivisection. "To begin with, proportion is forgotten. Suppose it capable of proof that by putting to death with hideous torment 3000 horses you could find out the real nature of some feverish symptom, I should say without the least hesitation that it would be unlawful to torture the 3000 horses." Now in the first place, supposing—as we must suppose if the illustration is to stand as argument—that the knowledge gained concerning the "feverish symptom" is to be knowledge useful in the saving of human life, we think that a truer note of "morality" is struck by Sir James Paget when he writes of a man whom he saw die under chloroform faultlessly given, "he was so good and generous a man that I felt it would have been right to kill a hundred animals either to save his life or to find out why he died, and to be able in the future to avert so awful a catastrophe." And if it is sound morality thus to feel that one hundred animals may be sacrificed to avert one such catastrophe, can it be otherwise to feel that three thousand animals may be "lawfully" sacrificed with the certainty of gaining assured knowledge—for this is the argument—which is to save many human lives?

But, in the second place, this brings us to the question of proportion, which is rather vaguely presented in Lord Coleridge's illustration. And on this question the physiologists are perfectly ready to join issue; in fact it is one of their strongest positions, and cannot be more tersely

stated than it is by Dr. Carpenter, whose very temperate and most judicious essay on the "Ethics of Vivisection," appears in the same number of the *Fortnightly Review*, and in this, as in several other points, anticipates Lord Coleridge's arguments in a manner singularly complete. He here says: "My argument then, is that if in all the foregoing cases (*i.e.* of animal labour, &c.) the moral consciousness of those who consider themselves most elevated in the scale of humanity justifies the infliction of animal suffering for what is obviously a real benefit to man, even though the continuance of such benefit involves the *constant renewal of the suffering*, much more is a *temporary and limited infliction* justifiable, for the discovery of such scientific truths as have a clear prospective bearing on human well-being, moral as well as physical, since every such discovery, once established, is a *boon for ever*, not only in its direct applications, but in serving as a stepping-stone to further discoveries, which may prove of still more priceless benefit."

Again, Sir W. Gull very properly asks: "Why does Lord Coleridge, for the purpose of his argument, select *horses*, and why so large a number as three thousand? He must know that the horse has been but little experimented upon . . . so that the supposition of *three thousand horses* and *hideous torment* is an exaggerated expression, out of proportion to the facts—misleading, and in no way conducive to a fair judgment of the question at issue." The truth is, it would be better for the cause which Lord Coleridge has embraced if "proportion" *could be* "forgotten"; for the strongest point in the counter-argument is that there is no comparison between the ratios—as Pain inflicted on animals for other purposes: Pain inflicted by Vivisection:: Prevention of Pain resulting from the former: Prevention of Pain, or other utility, resulting from the latter. And therefore, just because they do *not* forget the question of proportion, physiologists maintain that it is unreasonable in humanitarians to attack the only kind of "cruelty" that is really fruitful—and fruitful a hundredfold—in mitigating pain, not only in the case of man, but, as Mr. Fleming shows by his very astonishing tabular statements, also in the case of animals. Yet this essential argument has wholly escaped the observation of Lord Coleridge, and as a consequence he entirely misapprehends the subordinate argument of the physiologists who point to cases of admitted, wholesale, and useless kinds of cruelty as those towards which the energy of humanitarians should be directed. For he represents this argument as saying: Because there are many other kinds of cruelty of greater magnitude in the world, therefore "something which, *consistently with all this argument*, may be horribly cruel and utterly worthless, is to be let alone." Truly Lord Coleridge may be "positively mortified to have to notice" such an argument as this; only no one, so far as our knowledge extends, has ever advanced it. No physiologist could be simple enough to defend vivisection on the supposition that it "may be horribly cruel and utterly worthless." The real argument to which Lord Coleridge refers is this:—Because there are many practices permitted which are without question horribly cruel and utterly useless, therefore it is irrational folly to waste the energy of humanitarian feeling in a warfare against the only kind of pain-giving practice which is directed towards the mitigation of pain, and which has

already been successful in this its object to a degree *out of all proportion* to the pain inflicted.

If it is true, as the physiologists agree with Lord Coleridge in maintaining, that the ethics of vivisection turn upon this question of proportion, it becomes morally as well as logically incumbent on all those who take an active part in the anti-vivisection movement to make themselves acquainted with the facts by which alone this question can be determined. We therefore recommend all who are interested in the subject to read the very powerful essay by Prof. Gerald Yeo in the current number of the *Fortnightly Review*. This essay, when contrasted with that of Lord Coleridge or Miss Cobbe, exhibits in a striking manner the difference between knowledge and imagination, and therefore we do not think it can be said that the measured censure bestowed by this writer is too strong where he thus alludes to the above illustration of 3000 horses put to death by "hideous torment"—"I should have thought it impossible that a man who declares, 'I am not conscious of any distorting influence on my judgment; I have no anti-scientific bias,' could have suggested a case so horribly improbable. The extravagant irrelevancy of such a sacrifice, and its utter incompatibility with anything that can be called physiological research, are so manifest as to need no comment. Surely the writer cannot really imagine that such sheer brutality is within the range of possibility; or does he merely make the hideous suggestion in order to frighten those who have no knowledge of the matter? I refer to this sentence simply as an illustration of how unfounded and inaccurate ideas sometimes originate. For there can be no doubt that the mere mention of this appalling problem by such an authority, however repugnant it may be to common sense, cannot fail to leave some very unpleasant traces in the minds of many who imagine that a Lord Chief Justice would not undertake to write articles in a leading review, unless he had some accurate knowledge of the practical bearings of the subject."

Prof. Yeo has written his article in order to place such knowledge within reach of the general public, and he has evidently done so with the honest purpose of being "accurate." He says: "The exact relation of painful experiment to physiology may be best seen in a short analysis of physiological methods. Practical physiology is made up of four departments, in which its histological, chemical, physical, and vital branches are respectively studied. . . . Thus in fully three-quarters of practical physiology living animals do not appear at all. All vivisections are found in the fourth branch of physiology, but even here they form a very small part, for a large number of experiments on living animals (including man) are carried on without either cutting or pain." Taking then the subdivision of possibly pain-giving experiments, Prof. Yeo gives an analysis of the Parliamentary Reports during the last five years, in order to get at the precise number of pain-giving experiments which, during that time, have been made in this country. From these figures it appears that about three-fourths of the possibly pain-giving experiments were rendered painless by the administration of anæsthetics, and of the remaining fourth, four-fifths were "like vaccination or the hypodermic injection of morphia, the pain of which is of no great amount." The tabular percentage is, therefore, as follows:—

Absolutely painless	75
As painful as vaccination	20
" healing of a wound	4
" surgical operation	1
100	

Thus, since the statistics have begun to be taken under the new Act, it is a matter of numerical statement that in this country only 1 per cent. of experiments in vivisection are attended with pain greater than that caused by pricking with a needle or healing from a cut. Therefore we must here repeat our judgment that in this discussion it is shown to be the anti-vivisectionists, and not the physiologists, who have "forgotten" the question of "proportion"; for nothing can prove more conclusively than these figures that Lord Coleridge's statement of the case becomes true only if it is quoted with inverted meaning—"There is no proportion between the end and the means."

But Prof. Yeo is speaking of physiology as practised in England. Foreign usages he does not feel that it devolves on him to defend, and he appears to have an easy task where he shows that all the array of horrors which the anti-vivisectionists have been able to collect from the past history of physiological research have been derived from abroad. And it appears but fair argument to draw this distinction. This country cannot legislate for foreign physiologists, and no particle of evidence has ever been forthcoming to show that English physiologists are less scrupulous than the rest of their countrymen in their regard for animal suffering. On the contrary, long before the agitation began these physiologists themselves at the British Association formally laid down and formally accepted a carefully worded code of rules (quoted in the essay by Sir W. Gull) to guide their action with a view to minimizing of pain; and they have never, either collectively or singly, objected to legislation against possible abuses, while many of them have distinctly expressed their approval of such legislation. The long array of atrocities which constitutes the bulk of Miss Cobbe's paper is therefore quite irrelevant to any question in which this country is concerned. At most she can only argue, as Mr. Hutton argues—Because such things have happened on the Continent they *may* also possibly happen in England; and the answer is, By all means let there be legislation to guard against the possibility. And Prof. Yeo proves, we think conclusively, that the existing Act is abundantly sufficient for this purpose.¹

Another argument on the score of morality that has been advanced is one which is well and temperately stated by Mr. Hutton. He says: "You cannot take a step so certain to stimulate the thoughtless cruelty which still survives among us, as to sanction the deliberate infliction of a great mass of thoughtful cruelty, justified only by the prospect of ultimate benefit to man at the cost of untold agonies to his miserable fellow-creatures." But here, if the mis-statement of the "proportion" question presented by the concluding words is disregarded, it is evident that the point of ethics raised must be determined solely by consideration whether the "thoughtful cruelty" is *cruelty*—i.e. pain inflicted without an adequate

¹ It seems to require pointing out to Lord Coleridge and Miss Cobbe that to quote a brutal expression from any foreign physiologist is no argument for the abolishing of physiological experiment. Even if such expressions were English, or if the Royal Commission had found cases of abuse to occur in this country, there would be no such argument.

moral justification. And to assume that it is so is to beg the whole question.

Only one other argument of an ethical kind remains to be considered, and we are sorry to say that it has been advanced by Lord Coleridge—sorry because it is so childishly weak. It is the old argument that if the advancement of knowledge is taken to justify the vivisection of animals, as much or still more should it be taken to justify the vivisection of men; and in view of the horrible possibility thus supposed, Lord Coleridge exclaims—"I hope that morals may always be too much for logic; it is permissible to express a fear that some day logic may be too much for morals." Logic! Only on the assumption that an animal is a rational and a moral as well as a sentient creature, and that its reason and its morality are on a level with those of man, would the argument become logically valid; and it is just because the physiologists *do* "consent to limit the pursuit of knowledge by considerations not scientific but moral," that they are obliged to draw the same logical distinction between men and animals as that which is drawn by the Legislature.

Coming lastly to the side of Religion, Mrs. Kingsford concludes her article with a paragraph which we think worth quoting, as it may serve to indicate the value of her opinions generally: "If I should be asked what is the real position taken by the leading champions of 'free' vivisection, and concealed from the public under the plea that the practice conduces largely to the benefit of humanity, I would define it thus:—

"1. Repudiation of the religious and sympathetic sentiments, and of the doctrine of man's moral responsibility as superstitious and untenable.

"2. Deliberate determination to dissociate themselves from all but those who join in such repudiation; and to make the practice of experimental physiology on living animals a rallying-point for the expression of that determination."

Surely it must appear to Mrs. Kingsford that these "leading champions" are adopting somewhat roundabout means to secure their very remarkable ends.

Lord Coleridge asks: "What would our Lord have said, what looks would He have bent upon a chamber filled with 'the unoffending creatures which He loves,' dying under torture deliberately and intentionally inflicted?" And Prof. Yeo answers: "I cannot imagine any such chamber of horrors, any more than I can his other hideous suggestion;" and adds that concerning the real facts of vivisection as performed in this country, "my conscience unhesitatingly tells me that it would have met with the full authority and approval of our Lord. . . . And I like to bear in mind the texts which seem to have an accurate bearing upon the subject, 'Ye are of more value than many sparrows,' 'How much then is a man better than a sheep?'" Similarly Sir W. Gull and Dr. Carpenter support physiological research on grounds of Christianity and Theism, and it is evident that the religious side of the question really hinges on the ethical. If vivisection is cruel, it is also irreligious; but if it is the highest mercy, physiologists may claim, though from those to whom their work has been of priceless value they may not always receive, the beatitude of the merciful.

FISHER'S "EARTH'S CRUST"

Physics of the Earth's Crust. By the Rev. Osmond Fisher, M.A., F.G.S. (London: Macmillan and Co., 1881.)

MR. FISHER is well known to geologists as the writer of various important papers on Mountain Chains, Terrestrial Heat, and other physical phenomena of the earth. He has in this volume not merely collected these papers, but added so much new matter that they form only a small part of the book. It deals with those regions whither we cannot penetrate, and might be called a Treatise on Concealed Geology.

It has been made a reproach to geologists that their mathematics never get beyond the Rule of Three. Mr. Fisher may redeem them from the reproach. Indeed an unmathematical reader, when he sees pages covered with symbols, may be tempted to close the book in despair and imagine it a case of *μηδεις ἀγεωμέτρητος ἐνείτω*. However he would not act wisely. If he read steadily on, only omitting such calculations as he cannot understand, he will obtain many fruitful ideas, and follow several chains of sound and careful reasoning.

After a discussion of the rate of increase of temperature met with below the surface of the earth (which he concludes by adhering to the customary view of a uniform rate) Mr. Fisher reprints his former calculations of the enormous and overwhelming pressure to which the crust of the earth would be subjected, if the interior shrank away from it by contraction. The pressure would be such as the strongest rocks could not resist. The engineers of the St. Gothard Tunnel were almost baffled in attempting to sustain less than a mile's thickness of yielding rock. What arches or rings, what metal or granite would stand two thousand times that stress? There can be no doubt therefore that contraction is a cause adequate in intensity to contort any strata however thick, or uplift any continent however lofty. Adequate in intensity most certainly; but has it been sufficient in quantity? This question Mr. Fisher next considers. The answer will probably surprise many geologists.

When the earth first formed a solid crust with a glowing nucleus reaching to within a few feet of the surface, the nucleus would begin to cool and contract. As it shrank, the shell settling down on to it must crush itself into wrinkles. As successive internal portions solidified and were united to the solid crust, the remaining nucleus would continue to shrink, and the volume crushed out from the crust in process of accommodating itself would grow correspondingly greater. The wrinkles would be magnified. From Sir W. Thomson's formulæ for the internal temperatures of a cooling globe Mr. Fisher calculates the total volume of the wrinkles that could have been produced by now. He shows that this cannot possibly be so much as the fifteenth part of the volume of continental elevations above the sea bottom: more probably not even the sixtieth part. Though he considers the nucleus fluid, while Sir W. Thomson thinks the whole globe would have been solid or nearly so, this does not seem to affect the correctness of the conclusion. At the same time this cause, inadequate for continents, might yet be abundantly sufficient for the existing mountain chains, and for many predecessors of them.